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# TECHNICAL MEMORANDUM

November 10, 1964

To: W. Gores

From: P. D. Hess

Subject: Thermal Conditioning and Control Subsystem - Development Plan, Activity 145-195

Distribution: J. L. Platner, D. P. Ghere, R. E. Lochen, J. R. Hurley, C. Martin, G. Johnson

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## 1.0 FUNCTION

The Thermal Conditioning and Control Subsystem raises the FCA temperature from 60° F to 185° F $\pm$5° F in one hour and maintains 195 $\pm$5° F temperature throughout the operating period, refer to Paragraph 3.1.3 of Centerline Specification NAS 8-2696-S-00024. To accomplish this a secondary coolant of either helium or hydrogen will be circulated past the module fins and through a heat exchanger, by means of two axial fans and a system of ducts and baffles. The secondary coolant system will be completely contained within the module canister.

The vehicle coolant will be circulated through the heat exchanger in the canister and its flow will be controlled by means of a solenoid valve and a temperature controller. The total pressure drop of the vehicle coolant is not to exceed 5 psi. A relief type valve will be used to by-pass the flow when the solenoid valve is in the closed position.

Electric heating pads will be bonded to the secondary coolant ducts and used to heat the circulating gas during the startup period. Thermal switches of a sealed type will be mounted on the gas ducts to control the electric heaters.

## 2.0 STATUS

Two breadboard type FCA units have been designed, built and tested. These units consisted of a fuel cell module of 35 two-cell sections, and a heating/cooling subsystem using helium as a secondary coolant which was circulated past the module fins and through a heat exchanger by two axial type fans.

The tests on these units have shown the general design concepts to be adequate for a 2 KW system using helium as a secondary coolant. Approximately 135 pounds per hour of helium at 175° F to 195° F was circulated with the two fans which required about 175 watts of power. The fans are off-the-shelf items not specifically designed for this application. The $\Delta$ T of the helium across both the module fins and across the heat exchanger was about 18° F at 1.7 KW load. The $\Delta$ T of the fuel cell plate fins from center to end along the gas flow path was 6° F to 8° F and 3° F to 5° F along the stack height at this load.

The temperature control of the unit, when cooling is required, is accomplished by sensing module temperature with a thermocouple located in one hydrogen plate near the center of the stack, and a M-H temperature controller actuating a solenoid valve in the water primary coolant loop. Under low loads and during startup, heat is applied to the unit by means of heating the primary coolant and maintaining the solenoid valve in the open position.

The use of hydrogen as the secondary coolant would reduce the fan motor power to about 150 watts using the present fans and reduce the module fin $\Delta T$ about 1.5° F. The hydrogen secondary coolant system would require an oxygen sensor and control for purging the canister with an inert gas as a safety precaution.

## 3.0 DEVELOPMENT AREA

The development areas of the thermal control subsystem will be primarily of an engineering analysis nature and will have goals to reduce the fan motor power requirement through improved design of secondary coolant loop, improved temperature control components and provide thermal electrical heaters and their control.

3.1 Engineering analysis and tests should be accomplished in an effort to reduce fan parasitic power. The fan motor input power is dependent upon the pressure required to circulate the necessary quantity of secondary coolant, and the efficiency of the fan and motor. The secondary coolant requirements should be established by engineering analysis and by tests on the present breadboard systems. Fans and motors should be procured that meet the specific requirements with improved performance and efficiency.

3.2 Evaluate hydrogen versus helium as a secondary coolant considering safety, parasitic power, and total system weight.

3.3 Study and recommend means of increasing the system reliability of the fan system. For example, the use of more than two fans so that the failure of a single fan would not cause system failure.

3.4 Study and recommend improved heater configuration and design. The centerline design calls for the electric heaters to be molded into or bonded onto the baffles and duct system of the secondary coolant. It is expected that heaters can be purchased in a suitable configuration for use as the above items. A suitable hermetically sealed thermoswitch will be required to control the heaters. This thermoswitch must be selected and tested.

3.5 Work with and coordinate design of Thermal Control and Conditioning Subsystem with the EMCS design. The temperature controller is being developed in our laboratory as a part of the EMCS and is a solid state electronic device that will sense module temperature and actuate a solenoid valve. It is expected that the solenoid valve can be purchased as qualified component.

## 4.0 TEST PLAN

Test specification detailing the required testing and the required completion date should be generated as soon as possible.

P. D. Hess

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